Thesis/
Reports
Traxler,
V. L.
c. 1

79-12-389 c.1

TECHNOLOGICAL IMPACT EVALUATION OF A PLANNING MODEL

TECHNOLOGICAL IMPACT EVALUATION OF A PLANNING MODEL

Final Report for Cooperative Agreement
16-565-CA

by

Vickie L. Traxler

Colorado State University
Fort Collins, Colorado

September, 1976

ACKNOWLEDGMENTS

It gives me great pleasure to acknowledge the help of all who assisted me in the completion of this paper. First and foremost, I would like to thank my major professor, A. Allen Dyer, whose constant guidance, constructive criticism, and good humor will always be greatly appreciated. I am also thankful to the other members of my committee, Dr. Perry Brown and Dr. Ken Nobe, for their advice, assistance, and time. My gratitude also goes to Charles Palmer and Peter Ashton of Region 2 of the U.S. Forest Service for their professional and financial assistance in this project. They were responsible for acquiring funding for this study through the U.S. Forest Service. Deep appreciation goes to Greg Alward for his technical assistance and encouragement, and to all of my friends and colleagues in the Regional Resource Planning Program at Colorado State University whose moral support and friendship contributed greatly to this project's success. I wish to thank my dearest friend and husband without whose stubborn editorial and emotional help this work might never have been completed. A final note of thanks to Carole Travis. She had to work very hard to type this paper in a very short time.

ABSTRACT

Technologies induce impacts within and among natural, social, and economic environments. This study identifies criteria for models evaluating technological impacts. General technology assessment guidelines are reviewed. Additionally, specific criteria are derived for certain elements of technology assessment, technological change, technological externalities, and secondary effects. The criteria were applied to a conventional socioeconomic planning model developed by John M. Snyder for the U.S. Forest Service to determine capability with regard to the above three elements.

The study determined that the input-output analysis of the proposed planning model does not deal with technological change, externalities, or secondary effects, as defined. Other types of input-output analysis were suggested to replace or complement the proposed model with regard to technological change and external effects. Information exogenous to any input-output analysis is required for evaluation of secondary effects. However, multiplier analysis, as applying to interindustry methodology, was found useful for examining other types of impacts.

An input-output analysis, modified to consider certain types of technological changes, and especially externalities, was determined to be a useful component in a technology assessment program.

Vickie L. Traxler
Forest and Wood Sciences Department
Colorado State University
Fort Collins, Colorado 80523
May 17, 1976

TABLE OF CONTENTS

ACKNOWLEDGMENTS i

ABSTRACT ii

LIST OF FIGURES iv

Chapter
I. INTRODUCTION 1

The Problem 1
Purpose and Objectives 6
Organization of the Study 7

II. ELEMENTS OF TECHNOLOGY ASSESSMENT 8

General Technology Assessment Criterion 8
Setting for Technology Assessment 13
Induced Change 19
Summary 24

III. THE MODEL 26

Description of the Model 26
Evaluation of the Model 32
Alternatives to the Model 43

IV. CONCLUSION 55

Summary 55
Recommendations for Further Research 57

. . . . . .

SELECTED BIBLIOGRAPHY 58

LIST OF FIGURES

1. Production isoquant 15

2. Shifts in the production isoquant due to technical changes 17

3. Flow chart of the socioeconomic impact analysis system Source: Snyder, 1976 27

4. Conceptual input-output transactions table 30

5. Sample occupational labor force coefficient model Source: Snyder, 1976 31

6. The Isard model of ecologic-economic linkages Source: Isard, 1968, p. 87 51

CHAPTER I

INTRODUCTION

The Problem

Technology plays an important role in the life or the ordinary citizen. Witness the widespread use of the automobile, the television, and the electric light bulb. Other technologies are not commonly used by individuals yet may affect their lives, for example, insecticides, atomic energy, and computer systems.

Technology is defined as "any set of standardized repeatable operations that regularly yield predetermined results" (Freeman, 1974). Technology can be subdivided into two basic classes--human systems of thought and action, and systems of physical processes. For example, there are organizational technologies used by policy-makers, administrators, and institutions which produce policies or services. Physical processes include production technologies used to produce commodities, such as paper, steel, or petrochemicals.

A problem exists, however, when new technological developments are applied prior to consideration of associated impacts, or technologies are used indiscriminately without regard to depth and scope of impact. A few examples will suffice to illustrate the problem. The spread of the parasitic sea lamprey into the Great Lakes soon after construction of the Welland Canal resulted in the subsequent decline of the lake trout and whitefish population and thus the commercial and sport

fisheries industries (Elton, 1971). The widespread use of nonselective pest control chemicals, especially DDT, has disrupted food chains in natural ecosystems. Furthermore, some of these chemicals (due to long half-lives) will continue to inhibit reproduction in higher avian predators, such as the bald eagle, for years to come (Detwyler, 1971). The administration of large doses of estrogen to determine and prevent conception or as treatment for symptoms of menopause in women is correlated with the aggravation of cancer in those women and vaginal cancer in female offspring of those women (Nourse, 1976).

Several causal factors exacerbate potential for negative impacts of technology. With the increasing world population and the density of that population, technological developments affect ever greater segments of people. Forces of technological change have become so powerful that once instituted they can be difficult to reverse or correct. New technologies so alter social and natural environments that there is a decreasing margin for error. Also, the lag time from discovery and invention to widespread application is decreasing, resulting in less time for research to identify impacts associated with new technologies (Freeman, 1974 and Daddario, 1968).

Technological developments display certain effects of scale which are cumulative over time. For example, when the automobile was first manufactured, the resulting air pollution was negligible as the atmosphere was capable of assimilating the small amount of waste produced. The millions of automobiles in major cities now emit pollutants which affect atmospheric conditions in, around, and above the geographic area concerned. Furthermore, technological systems, like natural phenomena, are characterized by synergism which is defined as the "cooperative

action of discrete agencies such that the total effect is greater than the sum of the two effects taken independently" (Webster's Seventh New Collegiate Dictionary, 1970, p. 894). For example, the combination of private automobiles, super highways, communications, and refrigeration has had the effect of enhancing conditions for urban sprawl. The difficulty with synergistic systems lies in isolating any one causal factor. Indirect or secondary effects may only surface after long periods of time. The long-term effects of many substances are not known. The effect of DDT on carnivorous raptors was not foreseen when the chemical was first developed.

Technologies may also have secondary impacts on society. Employment opportunities create income which can be redistributed to people who consume goods and services which, in turn, generates more employment. Birth control pills primarily prevent conception, while secondary effects include aggravation of cancer and lengthening of the reproductive cycle in women. Tertiary effects include greater professional freedom and utilization of more human resources for production due to decreased child rearing responsibilities (Freeman, 1974). There exists a need then to evaluate technologies prior to application or implementation. Programs of technology assessment have been initiated to fill this information gap.

As early as 1937 the national government had recognized the need for a systematic approach to evaluate new technologies. In 1972, Congress enacted The Technology Assessment Act, with its primary impetus coming from Representative Emilio Q. Daddario. This act was intended to spur research to provide Congress with technical and objective information concerning the impacts of technologies and new technological

developments. Independent researchers (primarily universities), the National Academy of Sciences, the National Science Foundation, and the Office of Technology Assessment of the U.S. Congress have all been active in this field.

Daddario has defined technology assessment as "a method of analysis that systematically appraises the nature, significance, status, and merit of a technological program" (Daddario, 1968, p. 213). Coates states it as "the systematic study of the effects on society that may occur when a technology is introduced, extended, or modified, with special emphasis on the impacts that are unintended, indirect, and delayed" (Coates, 1974a, p. 30). Technology assessment then involves the identification, description, measurement, and analysis of technologies and their associated impacts.

Resource agencies, such as the U.S. Forest Service, may create impacts within and among systems by instituting new management plans or modifying previous ones. These agencies must base their decisions on information regarding repercussions of alternative courses of action. River basin planners perform impact analyses to evaluate alternate resource management plans. These plans are subjected to conventional regional science analysis, such as, input-output, economic base, cohort-survival and transportation-location models, to determine socioeconomic impacts upon a certain geographic area. Traditional socioeconomic impacts are typically evaluated as changes in total gross output of industries, employment changes, or population changes. A typical planning model is that developed in Agreement No. 16-428-CA by John M. Snyder for Region 2 of the U.S. Forest Service. This impact analysis model, hereafter called Model 428, was developed to measure socioeconomic

impacts of resource management plans utilizing secondary data sources to reduce costs. The model has four separate components; a regional economic model, occupation labor coefficient model, an employee to cohort allocation model, and a regional demographic model. Each will be discussed in detail in Chapter 3. The regional demographic component is a cohort-survival model. The occupation labor coefficient model and employee-to-cohort model are transitional techniques used to translate changes in total gross output in terms of dollars to cohort population changes in terms of people. The regional economic component, consisting of a conventional input-output model, comprises the driving force of the model and will therefore receive greater attention throughout the study.

While the model handles conventional socioeconomic impacts, resource analysts do not know if the model can deal with technological impacts for which it is difficult to assign market prices. Two classes of impacts of particular concern to river basin planners are discussed below.

(1) Technological externalities. Of primary concern to planners are those uncontrollable side effects of the production process. These externalities may be either costs or benefits that are not taken into account during economic transactions. For example, sulfur dioxide, an air pollutant given off during paper production, creates odors which are borne by society as an external cost of production. A benefit accrues to society and cost to an individual, however, when landowners construct sidewalks across their lawns for use by pedestrians. These side effects are difficult to put price tags on and are, therefore, left out of the conventional market transaction analysis.

(2) Secondary effects. One class of impacts deserving attention are those secondary effects due to increased production. Examples include the establishment of a cabinet industry in an area due to increased lumber production or potential expansion of industrial production due to increased final consumption.

Technology creates impacts within the natural, social, and economic environment. Resource management, a form of technology, imposes various impacts upon a geographic area. Conventional regional science models attempt to deal with those quantifiable socioeconomic impacts such as change in population or employment opportunities. But, a need exists to determine what technological impacts can be dealt with by conventional models or whether new models are needed. General technology assessment criteria may be of assistance in the field of resource management impact analysis.

Purpose and Objectives

Conventional planning models, such as input-output, economic base, demographic, and location models, do not handle the two types of impacts discussed previously--technological externalities and secondary impacts. Therefore it is the purpose of this paper to determine which, if either, of the two technological impacts can be analyzed within the modeling framework developed by Snyder.

The objectives of this study are twofold:

(1) To critically examine socioeconomic Model 428 with regard to analytical criteria for impacts of technological change, in general, and technological externalities and secondary impacts specifically, and

(2) To investigate alternative models and techniques which would facilitate analysis of technological change, externalities, and secondary impacts.

Organization of the Study

Evaluation of Model 428 with regard to technological impacts requires discussion of technology assessment criteria. Guidelines are formulated to derive some general technology assessment principles for impact analysis models. Following this, Chapter 2 contains a discussion of technological change, technological externalities, and secondary effects. The chapter discusses technological change, with special emphasis on technical change, and its relevant impacts on externalities and secondary effects. Additionally, specific criteria are set up for evaluation of technological change, technological externalities, and secondary effects.

Chapter 3 discusses the individual components of Model 428 as they occur within the model. The advantages, disadvantages, and potential uses of the model are discussed within the criteria derived in Chapter 2. Chapter 3 also identifies and discusses potential alternate models or techniques which may facilitate treatment of technological impact evaluation. Finally, the findings are summarized and recommendations for further research proposed.

CHAPTER II

ELEMENTS OF TECHNOLOGY ASSESSMENT

General Technology Assessment Criteria

Administrative and organizational systems have been accused of planning for technology rather than human beings. For example, timber managers are often characterized as fiber producers who pursue timber management without consideration of costs imposed upon aesthetics or community values. This tendency toward technological determinism has been increasingly subject to criticism as negative impacts from new technologies occur more frequently.

Technology assessment, as stated previously, involves the identification, description, measurement, and analysis of technologies and their associated impacts. Traditionally, technology assessment has occurred in reaction to a crisis situation when public insistence has demanded government intervention. Seldom has assessment occurred prior to implementation of that technology. Furthermore, government regulation of impacts has been gradual and fragmented in approach (Kasper, 1972 and Freeman, 1974).

Technology, itself, is often considered to be socially neutral; however, the impacts of technology can never have a neutral effect upon society (Freeman, 1974; Teich, 1972; and Brooks and Bowers, 1972). Each new technological development provides benefits or creates new possibilities of behavior for some, while at the same time imposes costs or

places restrictions on activities of others. A set of rational, systematic guidelines for determining trade-offs must be developed.

Several strategies for technology assessment programs have been formulated and proposed. Most are based on systems analysis techniques where the emphasis is on a holistic attempt at analysis. Listed below are the major themes of a system proposed by Overly (1972):

1) Establishment of goals and priorities
2) Prediction of future developments
3) Linkage of goals to future opinions
4) Analysis of organizational resources to meet those goals
5) Development of resource allocation strategy

Coates (1974b) proposes a more conventional outline for technology assessment models based on the scientific method, in addition to systems analysis.

1) Definition of the problem
2) Definition of alternative systems to be examined
3) Unfolding of impacts
4) Evaluation of significance of impacts
5) Decision apparatus identified and defined
6) Review and synthesis of above

Many matrix schemes of assessment have been proposed which are similar to environmental impact analysis matrices. In these models, components of natural, social, and physical systems and project actions are listed on each axis to enable determination of inter- and intra-system impacts (Ralph, 1972; Cetron, 1972; and Gordon and Becker, 1972). While these may be applicable to certain problem-solving situations, it is debatable whether or not their generality extends to all technology assessment.

General guidelines for technology assessment systems have been suggested in previous works. A summary of the major points follows:

(1) Any technology assessment system which proposes to measure impacts of technology must be easily adaptable to new situations and easily modified to accommodate changes in project design, impacts, or evaluation. The system must be a creative learning system which is responsive to new types of potential impacts (Freeman, 1974; Coates, 1974b; and Brooks and Bowers, 1972).

(2) A good technology assessment system will evaluate alternative management impacts with regard to reversibility. Planting trees on a certain area is a highly reversible action; the trees may be cut down and stumps uprooted if necessary. Farming processes take more effort to reverse due to nutrient loss or salt accumulation. Paving that same area with cement requires even more resources to return the land to a natural state. Using an area as test grounds for nuclear weapons is nearly irreversible due to the long half-life of the radioactive material. Designers of technology assessment systems should include criteria which measure the relative reversibility of alternative management impacts (Freeman, 1974 and Brooks and Bowers, 1972).

(3) Good technology assessment systems must examine certain characteristics of technologies prior to implementation, i.e., synergistic, secondary, indirect, long-term, and cumulative impact characteristics. Examining technologies for threshold effects may be one answer. Impacts of technologies may reach

a critical threshold level after which the system is unable to assimilate future effects and is no longer viable as an orderly system. For example, stream sedimentation is a common impact of logging operations. At what point is aquatic life unable to accommodate increases in turbidity and biological capacity of the stream for life support is negatively affected beyond correction? At what point in time will the stream itself dissolve as a physical system due to unnaturally high levels of silt or other types of sediment load?

(4) Technology assessment must be capable of identification and analysis of externalities. Externalities, defined previously, are imposed as costs or benefits to society, considered external to the market system, and therefore, not included in economic transactions unless forced by government regulation. Vested interest groups do not adequately assess external costs or benefits accruing to society from the development of a new technology. In general, spillover effects that benefit society tend to be financially underprovided (such as benefits associated with public education) while negative activities which generate spillovers tend to be overprovided and undercontrolled (such as air pollution from automobile production) (Freeman, 1974).

(5) Researchers should devise technology assessment systems such that burdens of uncertainty are allocated in the beginning of a technological development to society. Once the innovation has been fully developed and implemented, the producer should bear the proof of validity. Currently, groups challenging

technological developments must pay the costs of questioning frozen technologies. Risk allocation is necessary because technological developments are often frozen into patterns difficult to reverse due to the high sunk costs of resource use. A good assessment system should investigate a technology's impact "before it is allowed either to proliferate or stagnate" (Freeman, 1974, p. 127).

(6) A good technology assessment system provides for adequate public representation of impacted groups. In today's society there is a lack of organized constituencies with channels to confront decision-makers or challenge vested interests. Diverse social groups are difficult to unify and mobilize in response to negative impacts, whereas corporations have a great deal of influence and resources which can be used to sway legislative opinion. Location of impacted groups, such as those receiving the benefits or paying the costs of external effects, would facilitate constituency identification for technology assessment purposes. Assessment systems must be sensitive to public criticism and must provide means for constituency evaluation and feedback (Kasper, 1972 and Freeman, 1974).

(7) Finally, technology assessment systems must not be used to justify predetermined notions. It must be remembered that technology assessment systems are only as valid as the information or data base used. More importantly, the criteria chosen to evaluate the technology will always, overtly or inadvertently, reflect the biases of the assessor (Ralph, 1972 and Overly, 1972).

The above criteria provide guidelines for technology assessment programs.

While river basin planners assemble and evaluate information in order to formulate resource management plans, technology assessment systems complement the planning process. Technology assessment systems provide a method for analysis of impacts associated with management plans. Often resource planners choose a particular management scheme without knowing the impacts resulting from implementation of that plan. Technology assessment provides a means for comparing the various impacts brought on by technological developments or changes imposed by management plans.

Technology assessment systems, like any good planning system, provide a list of options and analyze the consequences of implementing any one option in particular. Therefore, technology assessment systems are only intended as an aid in the decision-making process, not as the decision-making process itself.

The Setting for Technology Assessment

While the above criteria provide a general framework for technology assessment systems, more specific guidelines are needed by resource agencies for analysis of particular impacts of technologies.

Technologies may cause impacts by creating new systems of thought or organization; or redistribution of inputs per unit output. These changes are imposed by decision-making agents, such as the U.S. Forest Service, who institute plans managing institutional and physical systems. For example, when the Forest Service institutes new timber harvesting methods, changes in stream sediment loads, local employment, and scenic landscapes may occur.

Technical change in production processes may be thought of as one type of technological change. Furthermore, for the purposes of this

report, technical change is considered representative of other types of physical changes and institutional changes. A brief consideration of traditional technical change concepts clarifies the types of phenomena a technology assessment procedure must identify. Assuming the production function concept generally applies to other types of technological change, specific criteria may be devised for evaluation of the planning model developed by Synder.

Classical economic theory defines technical change as that part of an increase in output not accounted for by increases in labor or capital stock (IR&T, 1971). This implies changes in production processes, which increase output per unit input, used to manufacture goods and services.

Mansfield (1971) states that technical change in production results in a shift in the production isoquant for a particular manufacturing process. Carter (1970), on the other hand, defines technical change as a change in a parameter of a particular mathematical form of a production function. Essentially these statements have an equal meaning which can best be explained through diagrammatic and mathematical illustrations.

A production isoquant is a curved line representing certain combinations of inputs that produce a given level of output. An isoquant may be thought of as a graphic representation of a production process. In Figure 1 on page 15, the isoquant shows all combinations of inputs, here, capital (K) and labor (L), which will produce 40 units of output. Both 4 units of labor combined with 7 units of capital and 3 units of capital combined with 10 units of labor will produce the same 40 units of output.

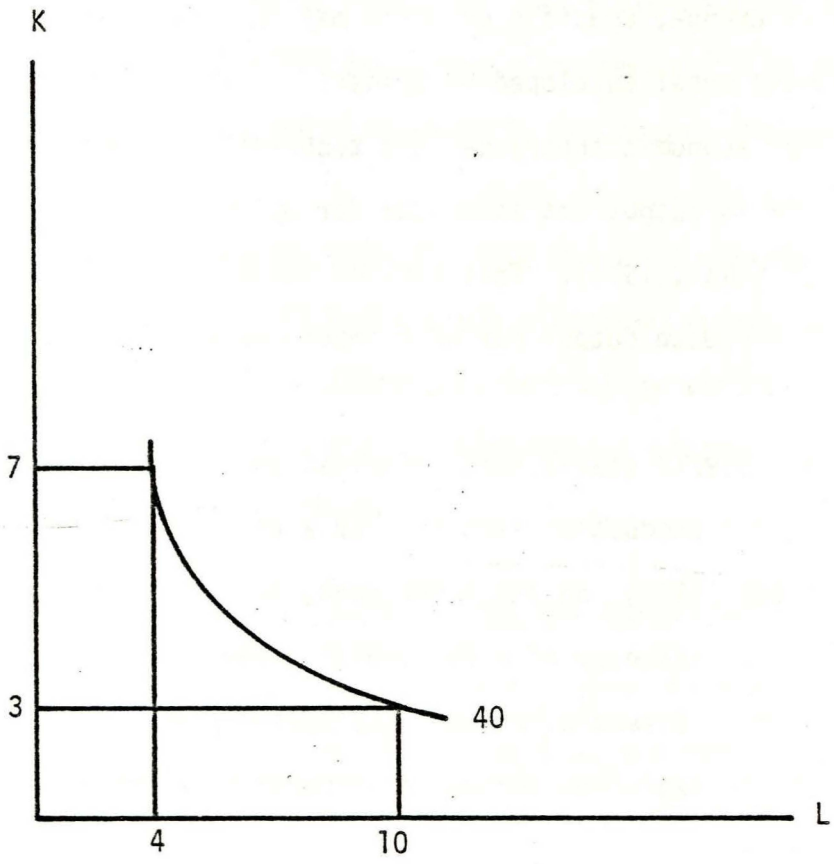

Figure 1. Production isoquant.

A production function is a mathematical equation representing a production process. One such equation, which represents the production isoquant in Figure 1, is

$$Q = f(K,L) \tag{1}$$

where output (Q) is a function of the two inputs, capital (K) and labor (L). A technical change function A(t), may be inserted into the above equation to include technical change over time. This represents all those factors other than capital and labor which go into production. Our sample production function then becomes:

$$Q = A(t)f(K,L) \tag{2}$$

This equation is a mathematical representation of a certain production recipe used to manufacture a particular commodity. In economic theory, there are three ways in which technical change affects a production process (Nicholson, 1972):

(1) Neutral technical change affects all factors of production equally by a change in A(t) such that $Q = [A(t)f(K,L)]$.

(2) Technical change in capital is a second way where only changes in capital affect production progress. $Q = f[A(t)K,L]$.

(3) Technical change in labor consists of only those changes in labor which affect production progress. $A = f[K,A(t)L]$.

The isoquant for a production process will shift as any one parameter in a production function changes.

Diagram "a," page 17, illustrates a neutral technical change where all factors of production are affected evenly. In this case new efficiencies in the production process have resulted in the shift of the isoquant from 1 to 2. Line 1 produces the same amount of output as 2 but with equally less inputs of capital and labor.

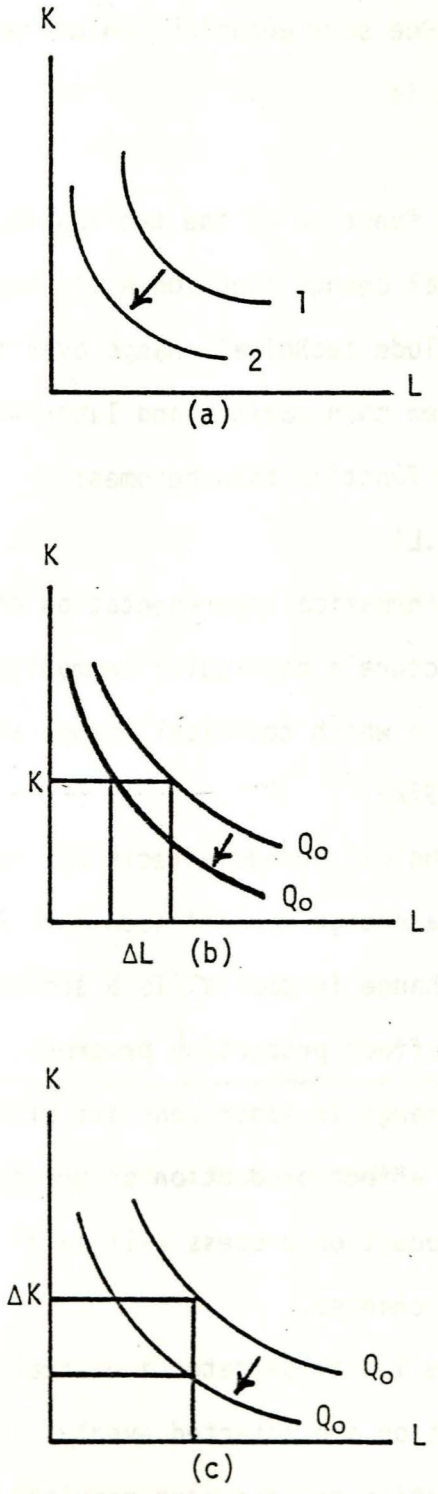

Figure 2. Shifts in the production isoquant due to technical changes.

Diagram "b," page 17, illustrates an increase in the efficiency of labor with respect to capital. Here isoquant 2 has shifted into the position of 1 and less labor is required to produce the same amount of output, holding capital constant.

Diagram "c," page 17, illustrates an increase in the efficiency of capital with respect to labor. The isoquant has shifted from position 2 to 1 as capital produces more output per unit input than previously. Labor input in this case then stays the same.

Therefore, the definitions of Mansfield and Carter state that a change in any one parameter of the production function will shift the isoquant representing that production process in either of the three ways above or in any combination of those three.

In this report technical change incorporates both entirely new production processes and also changes within a certain production process for a certain commodity. Hereafter these changes, for the sake of clarity, will be labeled Type I and II, respectively.

Type I changes are considered exogenous to the production process. Therefore this type of change is not represented mathematically within the production function but rather would require the derivation of an entirely new production function to represent the new manufacturing process. An example of Type 1 technical change is the development of the light bulb by Edison in the early 1900's or the introduction of fiber board into the construction market.

Type II changes in technical progress are usually embodied within the capital stock portion of the production function. In this case newly purchased equipment will have certain modifications different from old equipment characterized by increased efficiency within the

production process for a particular item. Examples of Type II changes include conversion to chainsaws in timber harvesting or conversion from Kraft paper processes to alkaline oxygen pulping processes (Marshall, 1976).

In economic theory, substitution is differentiated from technical change. Substitution implies changes in the relative price or quality of an input to a production process over time while technical change would consist only of improvements in the technique of production, i.e., changes in production processes which would increase the efficiency of a particular process. This study will adhere to these distinctions.

A model used to identify or analyze technical changes must then be able to (1) identify new production processes (Type I changes) as they are introduced into the market system; (2) locate improvements within production techniques (Type II changes), i.e., changes in the parameters of production functions; and (3) differentiate substitution due to price or quality changes versus technical changes in production (Type II changes).

Similarly, a model attempting to measure impacts imposed by technological changes, whether physical or institutional, must be able to identify new technologies and describe induced changes which modify traditional technological processes.

Induced Change

Technological changes imposed by decision-makers affect two impacts (among others not discussed in this report) of concern to resource planners: technological externalities and secondary effects. For example, technological change creates new processes of abatement or

control for external costs imposed by economic agents. Additionally, changes within technologies may create new kinds of externalities or increase or decrease previous ones. For example, the development of kraft paper processes resulted in increased acidity of streams and lakes used as waste depositories. Technological change may also induce secondary effects by creating new methods of production processes which increase output. Increased yields in timber harvesting due to implementation of plant genetics information creates potential for expansion in industries utilizing timber in their manufacturing processes.

Resource agencies act as agents of change by implementing management plans, e.g., designating resource harvesting techniques, managing wildlife resources, and specifying type of resource development for an area. Resource planners must utilize methodologies to quantitatively measure the impacts imposed by management plans. The following discussion details two kinds of induced change, technological externalities, and secondary effects, and sets up criteria for models attempting to measure these changes or impacts.

Technological Externalities

An externality exists whenever outputs of an economic agent appear as inputs in the consumption or production vector of another without payment (Buchanan and Stubblevine, 1962 and Holterman, 1972). These extra impacts generated by production are considered external to the transaction process when not included in the purchase price. Technological changes impose impacts upon humans and their environments. Some of these impacts, externalities, go uncompensated because they are unpriced in monetary terms.

Economic transactions involve the transfer of a good or service in return for a payment from the purchaser to the seller. Sometimes, however, prices are arrived at which do not reflect the real cost of producing that particular commodity. In other words, an individual or groups of consumers do not pay the full costs of producing the particular commodity they have purchased. Conversely, an individual or group of consumers may pay the full costs of producing an item from which others receive the benefits. All external effects have two properties: (1) interdependence--where an individual's actions create costs or benefits affecting others, and (2) lack of compensation--where an individual creates costs not paid for or creates benefits not received (Hite and Laurent, 1972).

Externalities may be represented by the following notation:

$$A = (X_{1A}, -X^{E}_{1A}, X_{2A})$$

$$B = (X_{1B}, X_{1A \cdot B}, X_{2B}$$

where A,B are consumption or production vectors of consumers or firms,

X_{ij} is the input of good i to agent j, i = 1,2; j = A,B, for X_{1A}, X_{2A}, etc.

$-X^{E}_{1A}$ is an unpriced output associated with A's use of 1,

$X^{E}_{1A \cdot B}$ is an unpriced input to B from A's use of 1.

The externality is $X^{E}_{1A \cdot B}$ in this framework (Krutilla and Fisher, 1975, p. 27). In order that this type of model adequately describes externalities in the real world, specific interdependencies between economic agents (A and B, and for that matter, C and D) must be quantified. Agents A, B, C, and D should be identified especially with regard to who pays for or creates costs and who pays for and receives benefits.

Intermediate outputs (X_{ij}) to the production or consumption process should be evaluated for their real costs of production including costs of externality abatement or control.

Externalities are important to natural resource managers who are involved in decisions concerning a particular resource use. Resource agencies must have information on external costs or benefits associated with a particular use. For example, management of national forest lands includes supervision of range, recreation, mining, and timber harvesting activities. The U.S. Forest Service should consider the external costs or benefits associated with each of these activities prior to adoption of specific development themes. While resource agencies are primarily concerned with impacts on natural resources, decision-makers should also be cognizant of human and social resources. For example, mining activities contribute to local community life by affecting traffic activities, service facilities, business income, and community values.

For an impact analysis model to adequately assess externalities associated with different production activities, the following criteria must be considered:

(1) Evaluation of resources for prices reflecting real costs and benefits involved with use;

(2) Quantification of externalities associated with individual activities;

(3) Determination of real costs for externality abatement or control;

(4) Identification of resource users imposing external costs or receiving external benefits; and

(5) Inclusion of external effects difficult to quantify, such as aesthetics, community values or other social indicators.

Secondary Effects

Another type of technological impact discussed is that of secondary effects stemming from increased production. Secondary effects differ from technological externalities. Technological externalities are unpriced outputs of a production process, whereas secondary effects are increases in priced outputs allowed by technological changes.

Prest (1965) defines "stemming from" effects as forward linkages resulting from increased production. For example, genetics research for tree improvement has produced higher yields of timber through quality selection. The increase in timber output generated greater quantities of pulp for paper production. This, in turn, enabled expansion of production in the container industry. In that sense, increased yields of timber fiber may imply increased lumber production for construction purposes, assuming consumption in the timber industry was also increasing. Thus, the home-building industry would be able to increase the number of houses built. "Stemming from" effects in production, which are made possible by increased output of primary inputs, then may be seen as secondary impacts. This type of linkage also happens in reverse. Industries, expanding to fulfill consumer demand, require increased supplies of capital stock, i.e., equipment and materials. Output of other industries will also expand to fulfill this demand.

In this study, emphasis is placed on one particular secondary impact as a variation of the traditional "stemming from" effect described above. In this case, secondary impacts are those effects of increased

production where new industries or firms may be brought into a region to utilize excess supplies or demand for inputs created by increased production within another industry. Examples include the establishment of a paper mill in a region where increased yields of timber have made possible the production of large amounts of pulp; and the establishment of a meat packing plant in an area utilizing increased beef production due to more effective range management.

Model criterion for measurement of this technological impact, i.e., secondary effects, consists of the location of a certain threshold level in production for each particular industry included within the model. At this point, increases in output warrant the establishment of a second different industry dependent upon the output produced by the first industry. This would necessarily imply knowledge of consumer demand for the commodity to be produced, availability of other inputs needed by the newly established industry, and individual firm practices. Knowledge of firm practices includes market analysis, transportation analysis, risk analysis for inducing industrial establishments appropriate for each individual industry, and capital costs in the money market.

Summary

The above discussion has set up an analytical framework for evaluation of Model 428 developed by Snyder.

Model 428 was designed to evaluate conventional socioeconomic impacts. In light of this, the model may be useful within a technology assessment system for impact analysis. General guidelines for technology assessment systems were summarized from the literature for this purpose. These criteria included adaptability, impact reversibility,

analysis of external effects, consideration of risk allocation, provisions for public representation, validity, and analysis of certain types of impacts such as indirect, synergistic, long-term and cumulative.

Technological changes or new developments induce impacts within natural, social, and economic environments. Technical change within production processes was chosen as representative, conceptually, of technological change. Criteria were derived to determine the economic model's capability for evaluating technical change, specifically, and technological change, in general. To review, a model used to analyze technical change must be able to identify new production processes and locate improvements within production techniques.

Resource agencies become agents of change by instituting new management plans, i.e., organizational technologies. These management plans create impacts on relevant environmental systems. Therefore, criteria were also set up to measure two technological impacts of concern to resource planners, externalities and secondary effects. Criteria for externalities were price assignment to external effects and their abatement, identification of resource users, and evaluation of social externalities. Analysis of secondary effects requires identification of production threshold levels, firm marketing practices, consumer demand, and consideration of input availability. The above criteria were applied to the model to determine its capability for analysis of technological impacts and technological change.

Analysis of technological change and impacts is an important concern of a good technology assessment system. Therefore, the model's capability with regard to the above largely determines its usefulness as a component of an assessment program.

CHAPTER III

THE MODEL

Description of the Model

The impact-analysis model devised by Snyder is a series of regional science models consolidated into a single package for convenience. The model measures conventional socioeconomic impacts imposed on the surrounding environment by alternative management plans. Should readers be unfamiliar with regional science concepts, they are advised to refer to Isard (1960).

From a general viewpoint, changes in regional output are converted, by means of the model, to changes in employment and finally changes in population due to migration. The model then describes the effects of changes of economic activity on the structure of the regional economy and the size and composition of the labor force. The flow diagram on page 27 illustrates the sequence of model components within the entire system.

Regional Economic Model

Within the context of Model 428, the driving force of the model is an imput-output analysis since impacts generated by alternate management plans are first measured in economic terms, i.e., changes in production. The input-output component of the model is essentially a static, open regional model which can be closed on various accounts.

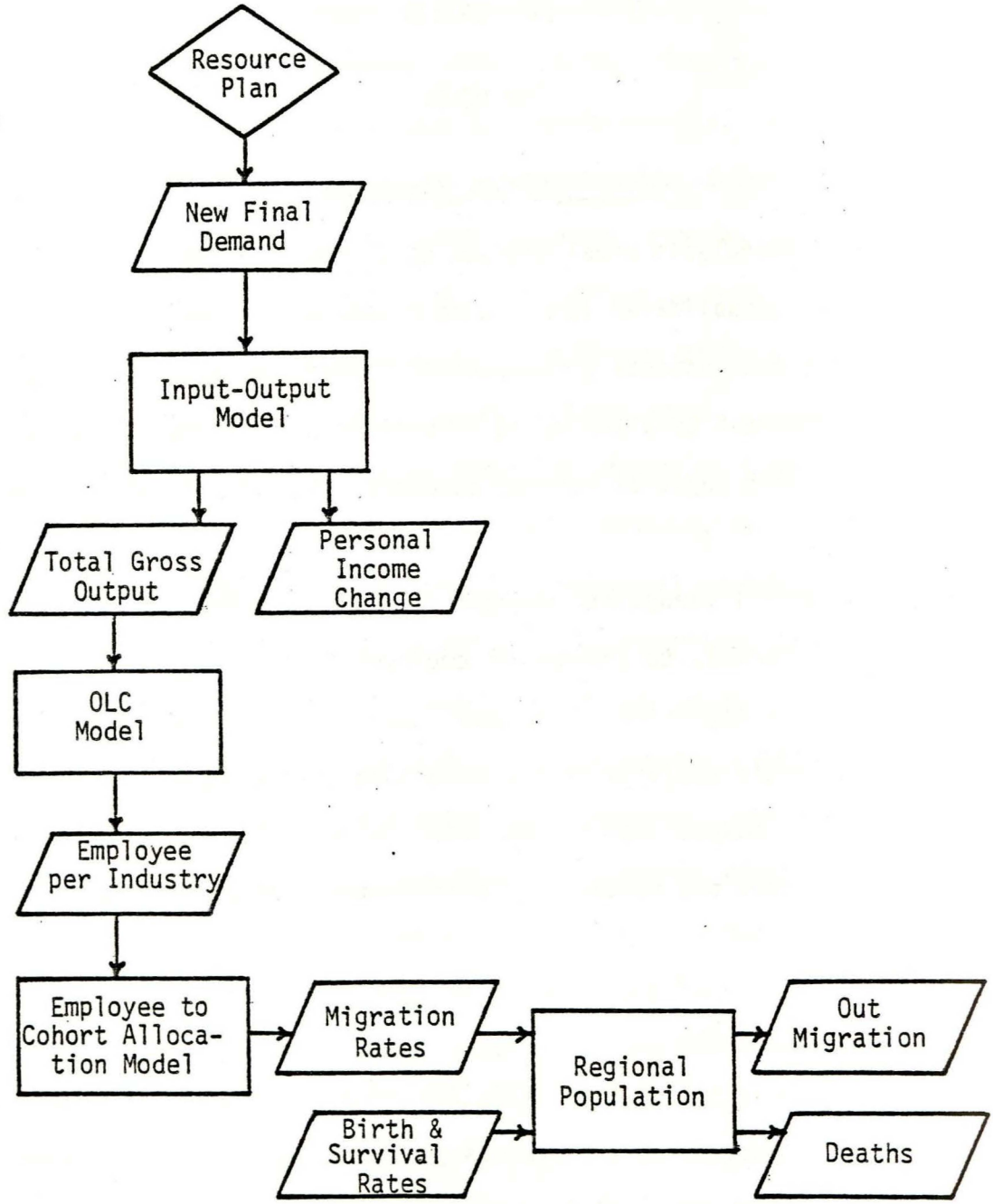

Figure 3. Flow chart of the socioeconomic impact analysis system.

Source: Snyder, 1976.

[For further information concerning input-output analysis in general, see Richardson (1972) and Miernyk (1965)]. Sectors included in the processing portion of the table are dependent upon the aggregation scheme and the objectives of the analysis for the region. However, emphasis in this model is placed on the natural resource industries of the region. United States Forest Service programs have been disaggregated into: "U.S.F.S. Timber," "U.S.F.S. Range," "U.S.F.S. Recreation," and "U.S.F.S. Other," all of which have been placed within the processing sector in order to better understand the effects of these programs on the regional economy. In addition, State and Local Government and Other Federal Government are also included within the processing sector to determine their economic impact on a regional economy. Households have been disaggregated from the Final Payments and Final Demand portions of the transactions table for inclusion with the processing sector. The placement of the Households sector is dependent upon the purposes of the study. If conventional economic multiplier impacts, business and income changes, are to be examined, Households should be included within the processing sector to determine changes in the economy due to changes in spending. In the Final Demand sector finished products are purchased for final consumption by government, other regions, and individuals. Final demand sectors consist of: Federal Government Expenditures, State and Local Government Expenditures, Gross Private Capital Formation, Net Inventory Change, and Net Exports. Final Payments generally include purchases from governments in the form of taxes, and payments to interests, rents, and dividends. Final Payments sectors consist of Value Added and Imports for this study.

The input-output analysis utilized secondary data sources except when U.S. Forest Service primary data were available for a particular sector. The National Input-Output Analysis of 1967 (USDC, 1974) provides the basic source of interindustry coefficients for the model. Location quotient techniques were used to adjust national transactions coefficients to regional coefficients in order that indirect and multiplier impacts appropriate to each region could be determined. The transactions table was also balanced to account for trade with other regions by adjusting import coefficients. For a general illustration of an input-output transaction table, see Figure 4, page 30.

Occupational Labor Coefficient Model

The Occupational Labor Coefficient (Economic Research Service, 1971) component is essentially a translation model used to evaluate regional changes in employment induced by changes in regional economic activity. Changes in total gross output of an industry will cause changes in the labor force required by that industry to produce goods and/or services. The production and employment of that industry also impacts other industries in that region, and therefore, the OLC measures indirect impacts similar to input-output analysis techniques. The OLC model, then, is similar in structure to the input-output model utilized in this project. The labor force classification scheme is identical to the sector classification used in the input-output analysis whereby total employment changes are disaggregated by industry, occupation, and skill level to determine impacts within particular groupings. Matrices are constructed to determine employment impacts due to changes in economic activity (see page 31, Figure 5). State census data and U.S. Forest Service data were used as sources for employment information in Model 428.

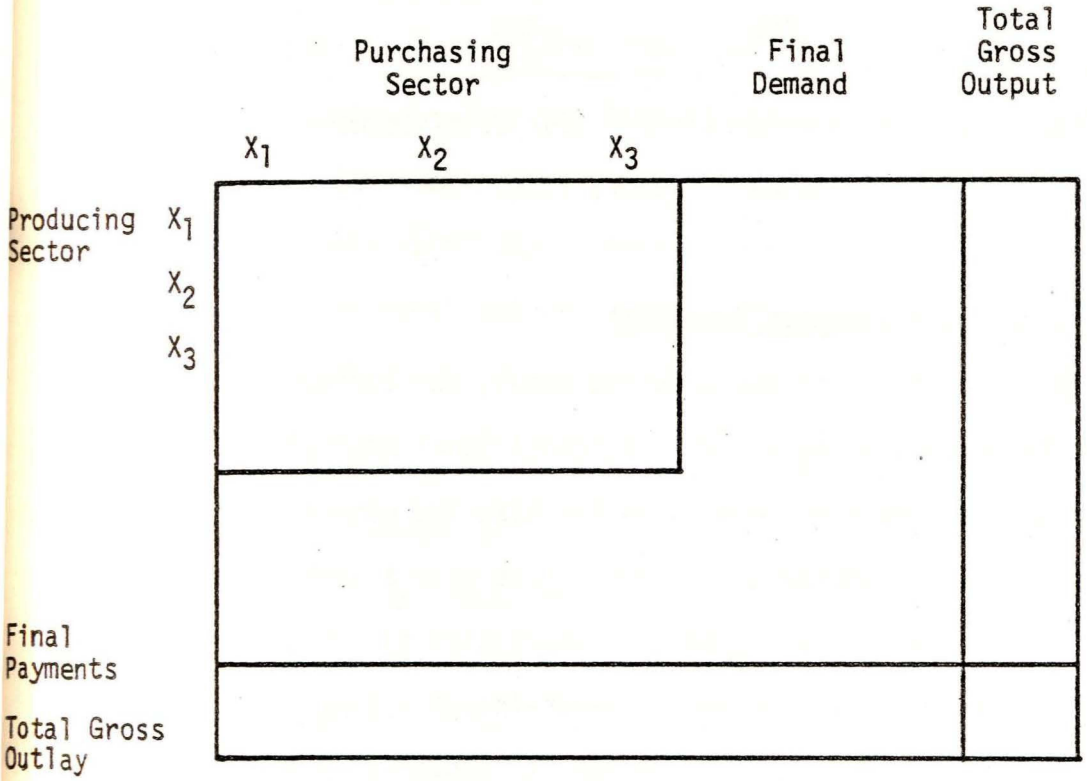

Figure 4. Conceptual input-output transactions table.

portion of the model evaluates initial economic impacts of a management plan and provides inputs to other model components. These other subsystems evaluate some sociological impacts (employment and population) which derive from economic change.

The structure of Model 428 is such that technological impacts cannot be assessed unless they interface with the economic component of the model. Changes in final consumption are fed into the model to determine changes in sales of intermediate commodities among industries. Therefore unless an impact is incorporated into data on final consumption, it cannot be assessed by the model. For that reason, this study will evaluate the input-output or economic component of the model, rather than the other three model subsystems, with regard to technological impacts.

Technological Change

Again, technical change is taken as representative of technological change.

A model to identify technical change must describe the production function representing the new technology or the parameter change of a production function representing a modification in a previous technological process.

Description of a new technological development (Type 1 technical change) requires the derivation of a new production function detailing inputs per unit output. Conventional input-output analysis describes economic transactions between industries and to final consumption at one point in time. The model describes the input structure of specified industries aggregated into sectors. Therefore, while the

input-output analysis delineates the economic structure of an economy, it can not identify new structures without a previous input-output model with which to compare. Additionally, unless specific categories of new commodities produced by the development of new technologies are included within the sectoring scheme of industries, the model can not describe the input structure required by the new industry for production of that new commodity.

A critical assumption of input-output analysis is the constancy of technical coefficients. Assuming constant coefficients implies a fixed production function and non-substitutability of inputs (Miernyk, 1965 and Richardson, 1972). To explain, technical coefficients represent the percentage of inputs required by one industry from all other industries. The technical coefficients then describe the input structure or technology of an industry. The assumption that these coefficients are fixed also defines a fixed production function describing the input structure. Technical change, however, requires that description of the production function include fluctuations of that function. Thus changes in the parameters of the production function, technical change Type II, are precluded by model assumptions.

It is possible to measure technical change within the input-output framework, provided input-output models are available for two separate time periods for the same geographic area (Carter, 1970 and Vaccara, 1972). The models can then identify changes in production processes (Type II technical change) by comparing input structure within industries concerned. However, it is difficult to determine from the information given by an input-output analysis whether the changes in input structure were the result of changes in production

processes or substitution due to price or quality changes. The model only identifies transactions in terms of market value of sales. Unless information on these types of questions are included within the initial industry survey used to gather the data base, the models cannot discern the reason for changes in input structure. Furthermore, Model 428, relying on secondary data sources, can only accept the initial transaction, upon which the analysis was based, as given. If primary survey work were initiated, this information might be obtained; however, the cost of the analysis would increase greatly.

As mentioned before, even if two data sets are available for comparison, new technologies (Type I change) cannot be evaluated unless provisions are made within the sectoring scheme for the creation of new industries and new production processes. Therefore, unless the change was occurring within an industry already specified by the sectoring scheme of the first data set, the new production process would not be identified.

Another technique used for analysis of technical change, also requiring two data sets, is concentration of changes within certain sectors, Research and Development, Investment, and Capital Stock (Miernyk, 1965; Carter, 1970; Richardson, 1972). Technical change in production processes (Type II) is assumed to be embodied in capital stock because modifications in production processes surface in capital, materials and equipment (Carter, 1970). Additionally, it is assumed by various researchers (Carter, 1970; Vaccara, 1972; Miernyk, 1965; and Richardson, 1972) that significant changes in Investment or Research and Development signal development of new technological processes. Model 428 is based on the National Input-Output Table for 1967 (USDC,

1974) which does not include measurement of transactions in the Research and Development sector. Additionally, the Investment sector is not disaggregated from Final Demand in this model. Due to the aggregation of the sectoring scheme in Model 428, even if two data sets covering a certain time interval were available, technical change in production processes, as evidenced in the sectoral transactions of Investment, Capital Stock, or Research and Development, would be difficult to identify with this model.

Forecasting techniques have also been used to determine technological changes (Miernyk, 1965 and Richardson, 1972). The above techniques require two models for different time periods over which period technical change is analyzed. Forecasting requires only one input-output model from which it projects intermediate demand for a time period in the future. Model 428 could be used as a base model from which a projected model is derived. However, the difficulty lies in predicting final consumption of goods and services at that future time period from which projections of intermediate goods are calculated. Furthermore, while technical change is evaluated by the technique, the projections are simply expansions of past and current trends of industrial production processes.

In conclusion, the input-output component of Model 428 cannot identify Type 1 and II technical changes in production processes because two data sets are not available. Technological change, as represented by technical change, cannot be evaluated by the model because the model describes economic structure at one point in time and therefore change is precluded by the model framework. Should two data sets be available, comparison of technologies may be used to evaluate technological change. However,

the model considers only physical changes measured in terms of monetary values excluding institutional or organizational changes in technology.

Technological Externalities

As pointed out above, technological externalities are of importance to resource agencies as these 'side effects' of production increasingly impact natural resource use. Therefore, it is important that economic models include analysis of external effects in order to provide resource decision-makers with a better information base from which to work.

The economic component of Model 428 consists of a conventional input-output model detailing sales of purchased goods between sectors and for final consumption. Because externalities are not included by definition in economic transactions, they cannot be evaluated by a model which considers transactions of commodities by market prices. Therefore the model cannot consider any other criteria relevant to externalities, such as identification of resource users, determination of real costs of externality abatement and control, or inclusion of social costs and benefits associated with production processes.

However, potential alternate models exist which can evaluate external costs and benefits, assign shadow prices or physical units to externalities and determine broad categories of resource users. There is also a possibility for the handling of non-quantifiable environmental goods utilizing input-output analysis. Some potential models and alternative techniques for possible adaptation to Model 428 are discussed in the concluding section.

Secondary Effects

The input-output component of Model 428 can provide information relative to secondary effects in that it identifies industrial output,

inter-industrial sales and final consumption. However, criteria for secondary effects are not dealt with in the economic portion of the model.

Model criteria for evaluation of secondary effects requires knowledge of individual firm practices and consumer demand for the commodity to be produced, neither of which are internal to the model framework. An input-output analysis simply describes the economic structure of an area. It does not predict future demand for commodities or incentives for establishment of new industries. Additionally, input-output analysis assumes unlimited input availability. The identification of a threshold level of production, where an additional industry can be supported by another industry's output or input requirements, requires information exogenous to the input-output model.

While unable to evaluate secondary impacts, the input-output technique has special relevance to income and output changes within an economy. The ability to measure relationships between industries permits evaluation of an industry's contribution to generated income or output. The input-output model has potential for three types of multipliers; business, income, and employment multipliers. A multiplier is simply a comparison of immediate effects with full effects of a change in the economy over time. A multiplier will then show the indirect repercussions brought about in the whole economy due to a direct change in some sector of that economy (Richardson, 1972 and Miernyk, 1965).

The business activity multiplier measures the sum of direct and indirect requirements or total business activity from all sectors needed to deliver an additional dollar of output of an industry to final demand.

There are two kinds of income multipliers designated as Type 1 and Type 2 in this report. The Type 1 multiplier takes into account the direct and indirect changes in income resulting from additional direct income paid to households by all industries in the processing sector. The Type 1 multiplier may be expressed as the ratio of the direct and indirect income change resulting from a unit increase in final demand in a sector. The Type 2 multiplier measures the direct and indirect effects plus the induced changes in income resulting from an increase in consumer spending. That is, the Type 2 multiplier measures the chain reaction effects induced by increased consumer spending in addition to direct income. Therefore, for each sector the Type 2 multiplier will be larger than its Type 1 counterpart. The Type 2 income multiplier is the ratio of the direct, indirect and induced income changes to the direct income change.

Employment generating effects of a particular sector may also be derived from the information presented. Given a ratio of workers per $1000 of income or a production per worker ratio, employment effects may be calculated. Model 428 provides methods of estimating employment impacts through the use of the OLC component of the model (Economic Research Service, 1971). The OLC model generates both direct and indirect employment changes due to changes in industrial activity determined by the input-output model. (For application of multiplier analysis to a particular area, see Appendix 1.)

Therefore, while Model 428 can determine business activity generated, Type 1 and 2 income effects, and employment changes due to changes in production, it cannot determine secondary effects.

General Technology Assessment Criteria

The economic component of the model was reviewed with regard to some guidelines for technology assessment programs, in general. For greater detail concerning individual technology assessment criteria, the reader is referred to Chapter II, section 1.

Input-output analysis can be used to identify some secondary, indirect and long-term impacts of technological developments. For this purpose, multiplier analysis, use of dynamic coefficients, and inter-industry forecasting may be utilized. The identification and analysis of external costs and benefits which can be quantified in either market or physical terms would also be facilitated by modified input-output techniques. Interindustry analysis can also be changed to accommodate variabilities in the problem situation. Sectoral categories and data can be adjusted dependent upon research objectives, and fiscal and time constraints.

Technology assessment criteria of reversibility of action, allocation of burdens of uncertainty, and public representation do not apply to this model.

While the input-output model is essentially a descriptive, value-free analysis of the structure of an economy at a certain point in time, the technique can be used to evaluate impacts of alternative mangement schemes. By comparing input-output analysis for each alternative, impacts of one alternative may be judged relative to other management plans. In any modeling effort, however, objectives may be chosen such that data input to the model is indirectly skewed. Therefore, when results of an input-output model are used to formulate policy guidelines, this initial statistical bias must be considered.

Input-Output Analysis

At this time, it is appropriate to consider the validity of input-output analysis in general. As stated previously, the model describes flows of goods and services in the form of monetary transactions between the industrial sectors of an economy at one point in time. Input-output analysis is typical of most regional science models. The model can adequately describe economic activity at one point in time, but it cannot accurately determine cause and effect relationships, changes in economic activity, or predict future economic activity. For example, researchers often use business and income multipliers to determine impacts of the establishment of a new industry or changes in the output of a particular industry. Yet these multipliers are derived from a static analysis which precludes economic change. Furthermore, because of the cost involved in updating interindustry data, older tables are often used as the information base for constructing management plans. Vaccara (1970) and Carter (1970) have found that interindustry coefficients may be considered accurate for a three-year period beyond the initial survey date after which time, they represent outdated technologies.

Additionally, the technique requires use of a primary survey for accurate data on transactions between sectors. That is, a percentage of firms from a particular industry are interviewed to determine individual purchases and sales to intermediate and final consumption. Clearly, this procedure is costly and time-consuming. Firms also may not keep detailed records of purchases and sales requiring estimates of this information. Secondary data sources, such as U.S. Census and Bureau of Labor statistics, are often used on a regional level to keep

costs of producing an input-output analysis to a minimum. Techniques have also been devised for transforming national primary-based inter-industry models into regional models. Model 428 uses the location quotient method for determining regional economic activity from the 1967 National Transactions Table (U.S.D.C., 1974). The location quotient technique in Snyder's model utilized employment data to determine the appropriate ratio. The location quotient is defined as:

$$LQ_i = \frac{E_{ir}}{E_r} \div \frac{E_{ius}}{E_{us}}$$

where LQ_i = location quotient from industry i

E_{ir} = employment in industry i for a particular region

E_r = total regional employment

E_{ius} = employment in industry i for the United States

E_{us} = total employment in the United States

While this technique regionalizes national economic activity, the results are only approximations of local transactions and may not represent a true picture of what actually takes place. Problems also occur when the national economy undergoes a drastic change. Snyder's model is based on a 1967 national table, yet since 1967 the economy has undergone significant depressed economic activity and is in the process of recovering. The fact that Snyder's model is based on nine-year-old technical coefficients and that the national economy has gone through boom and bust periods since that time, may lead planners to justifiably question the validity of the entire model.

Therefore, it is critical that resource planners realize the limitations of input-output analysis whether based on primary or

especially, secondary data. Input-output analysis may accurate describe intersectoral flows at one point in time if primary data sources are utilized. However, input-output analysis may only provide gross indications of industrial transactions and multiplier effects when secondary data sources are used or if the data is outdated. Other models should be examined for use in technology assessment programs which have greater reliability and adaptability, lesser cost on a regional level for primary data acquisition and updating of primary data.

Alternatives to the Model

While the input-output component of Model 428 does not evaluate any of the technological impacts discussed previously, there are certain modifications or alternative formulations of input-output models which do deal with these elements of technology assessment. The following review of alternative techniques and models suggests guidelines for future research in this area.

Suggested Techniques for Modifying the Basic Input-Output Framework

Linear programming. Linear programming methodologies have been suggested as complementing input-output analysis by providing solutions to problems with traditional interindustry assumptions. [For information on linear programming as applying to economics, see Richardson, 1972 and Baumol, 1972).] Input-output analysis assumes an unlimited supply of inputs to production and unlimited industrial capacity for production. No consideration is given to resource supply constraints, capacity of equipment or shortage of capital for investment purposes. Input-output analysis assumes non-substitutability of inputs to the production process; however, substitution within production processes is

well-documented (Mansfield, 1971; Carter, 1970; and International Research and Technology Corporation, 1971). Input-output analysis has been criticized because it is simply a description of an economy and does not prescribe directions for future economic growth or corrections for an economy's problems. Linear programming allows a goal-oriented approach for planning purposes by means of an objective function.

Linear programming is a technique whereby a solution may be obtained for a set of simultaneous linear equations. Thus, input-output analysis, also a set of linear equations, fits particularly well into this framework. Linear programming also allows the researchers to choose, by means of an objective function, one desired goal from among many production possibilities. This goal is a mathematical statement which maximizes or minimizes a particular input or output. Theoretically, for every maximization statement (the 'primal' problem), there exists a corollary minimization statement (the 'dual' problem) and vice versa. The dual solution of an output maximizing function will yield a set of shadow prices for inputs to the production process. Shadow prices are the maximum unit price one is willing to pay to increase the allocation of a resource to production (Baumol, 1972). The shadow price assigned to a particular resource would reflect the real value of so-called free goods within the production process. Decision-makers would then be able to formulate policies for resource use based upon the shadow prices determined by the model. However, there are some problems with application of this approach. Richardson (1972) suggests that empirical application of linear programming to natural resource uses is limited due to lack of data, lack of consideration of quality of resource imputs, and computer capacity constraints.

Technical substitution due to price fluctuation is another area where application of linear programming to input-output analysis may prove to be useful. In this case, model solutions may be repeatedly solved by fluctuating prices of inputs to production processes. Comparisons of differences in industrial input structure may then be examined. Other types of substitution may also be evaluated by imposing various constraints on the supply of inputs available for production and repeatingly solving for solutions.

Dynamic analysis. Application of dynamic analysis to interindustry models may also yield information on technical change. Conceptually, dynamic analysis details continuous flows of transactions over time. Empirically, dynamic analysis is difficult to implement because of the data flow requirements. However, transactions at discrete time intervals can be recorded and production input requirement changes recorded. This technique may point to some cause and effect relationships regarding changes in efficiency of production processes. Dynamic analysis may also provide information on economic repercussions from changes within technological processes over time.

Impact matrices. Impact matrices for analysis of resource use and social costs have also been suggested as providing valuable information on external effects within an input-output framework (Richardson, 1972). Essentially, coefficients are determined relative to the objectives of the analysis. For instance, if solid waste produced during production processes is to be measured, the amount of solid waste per $1000 of output is calculated to determine ratios for each industry concerned. An impact matrix is then constructed where each industry's contribution to solid waste per $1000 of output may be

detailed. Ramifications of one industry's increased output on the economy as a whole or other selected industries may then be calculated with regard to solid waste, or any other criterion. This type of analysis would not only identify direct and indirect resource users, or impact producers, but also would point out bottlenecks for resource use within an economy.

Bergman (1972) used this technique to analyze direct and indirect production of solid waste, danger to life and limb, and the employment of women for a 93-sector interindustry model of Maryland. More research has been done in the area of water use associated with production. Gray and McKean (1976), among others (Davis, 1967; Ireri, 1967; and Lofting and McGauhy, 1968), assigned water use coefficients to industries to determine impacts associated with changes in production output. Problems arise in that this type of analysis does not allow for resource quality changes or mobile or non-confined resources, such as air.

Hirsch, et al. (1972) has also suggested linking levels of social criteria to input-output sector outputs. Hirsch considered two alternate techniques; one estimating expenditures associated with particular indicators by specifying purchases and sales of a hypothetical activity and the other estimating expenditures required to achieve a target indicator level by including within the input-output model information on the quantity and costs of indicator production and abatement.

Proposed Alternate Models

Application of input-output to ecological systems. An input output model quantitatively measures interindustry production flows by disaggregating transactions among sectors. These distributions and

and relationships between sectors constitute economic ties effecting indirect impacts on industries from changes in consumption patterns. Traditional economic impacts of management plans may be assessed by the input-output model to determine changes in sales and employment. Thus the input-output model provides an analytical framework for evaluation of interindustrial transactions.

Components of ecological systems are also highly interdependent as materials flow between and among systems. Leontief (1970, among others, has suggested the potential of input-output techniques for evaluating those technological externalities which can be quantified, e.g., air and water pollutants and solid waste (Daly, 1968; Ayres and Kneese, 1969; Victor, 1971; Hite and Laurent, 1972; and Isard, et al., 1972). Use of input-output techniques would facilitate a systematic, objective method for analysis of supply and demand of environmental goods and flows between and within ecological and economic systems. Input-output analysis would also provide information with regard to direct and indirect consumption and users of environmental goods.

Ayres and Kneese (1969) elaborated on the 'spaceship earth' philosophy to form a materials balance view of production and consumption. They demonstrated that residuals from consumption are an integral part of the economic world and must ultimately be reused (unless population trends change or significant new technological developments occur) and therefore should be included within general equilibrium theory. In order for commodities to be produced, certain environmental goods are needed as inputs to production, and in turn environmental goods may also be generated during production. These

environmental outputs, along with other residuals obtained during or after consumption of a good's particular service (the good itself is not consumed entirely), are inputs to environmental systems from which environmental goods were initially drawn as inputs to production.

This type of analysis of inputs to and residuals from the production process would fit well in an input-output framework in conceptual terms. However, certain problems do arise when basic assumptions of the model are reviewed with regard to inclusion of ecological systems.

The Leontief input-output model (Leontief, 1936) assumes production delivered by industry i to industry j to be a linear and homogenous function of the output level of j with constant returns to scale. Additionally, technical coefficients are assumed to be constant over time, enforcing a fixed production function, i.e., only the proper and same combinations of inputs will produce a particular output. This also assumes non-substitutability of the factors of production and non-existence of joint products in production activity (Miernyk, 1965 and Richardson, 1972).

Relationships between economic and ecological systems are non-linear; therefore, the fixed coefficients assumption would be less appropriate (Detwyler, 1971). Furthermore, the assumption of no joint products in the Leontief model is violated when pollutants are produced in conjunction with certain commodities. In this case residuals may be produced when the good is manufactured, e.g., air and water pollution, and when the service of the good is consumed (pollutants or solid waste) (Richardson, 1972 and Ayres and Kneese, 1969).

Other problems, although not peculiar to this approach, include:

(1) Data aggregation--Bakery waste residuals differ from canning factory residuals yet both are included within the Food Processing sector (Standard Industrial Classification, Division D, Major Sector 20), muddling efforts to identify a polluting industry (Hite and Laurent, 1972);

(2) Lack of pricing mechanism--Free environmental goods have no market prices. Rather subjective criteria must be used to assign shadow prices if monetary values are used within the model (Richardson, 1972 and Hite and Laurent, 1972);

(3) Non-quantifiable environmental goods--Aesthetics and other qualitative environmental goods are difficult to assign monetary values to and are therefore eliminated from conventional input-output analysis which can only evaluate quantifiable commodities (Richardson, 1972 and Bergmann, 1972);

(4) Insufficient data--There is a lack of available data describing ecologic-economic, economic-ecologic, and especially inter-ecologic flows (Ayres and Kneese, 1969);

(5) Changes over time--Kissin (Hite and Laurent, 1972) states three limitations due to changes over time; changes in our knowledge about ecological systems, changes in technology which will drastically alter our lifestyle and changes in values we place on environmental quality.

While there are many criticisms of an ecologic-economic inter-industry model, analytical evaluation of externalities affecting resource use may generally provide some useful information. Design of

an ecologic-economic model would identify major direct and indirect polluting sectors of an economy for policy purposes. Application of input-output analysis to environmental goods would assist in explaining or anticipating effects of technological changes on the output of pollutants by industry. Economic-environmental analysis would then facilitate evaluation of external costs associated with alternate resources uses (Leontief, 1970; Hite and Laurent, 1972).

The Isard model. A potential model of notable importance is that developed by Walter Isard (1968 and 1972) for analysis of environmental externalities. The model utilizes a traditional input-output framework. Figure 6, on page 51, illustrates the Isard model. In Isard's conceptual framework the ecologic system may be viewed as a set of interdependent activities. These activities provide inputs to ecological system processes and furnish final output (exports) to the economic system. Ecological activities are also dependent on the economic system receiving commodities to be used as inputs. These inputs to ecologic systems are also considered as economic system exports to the exogenous environment. Ecologic and economic systems can be effectively linked by means of the exported and imported goods. Therefore, the economic system in the upper left of Figure 1 is a traditional input-output model. The ecologic system in the lower right details ecological exchanges paralleling the economic system. The lower left-hand block of the diagram details the imports from and exports to the ecologic system in coefficient form. The ecological processes matrix, the upper right-hand corner, lists in coefficient form the inputs and outputs of economic commodities.

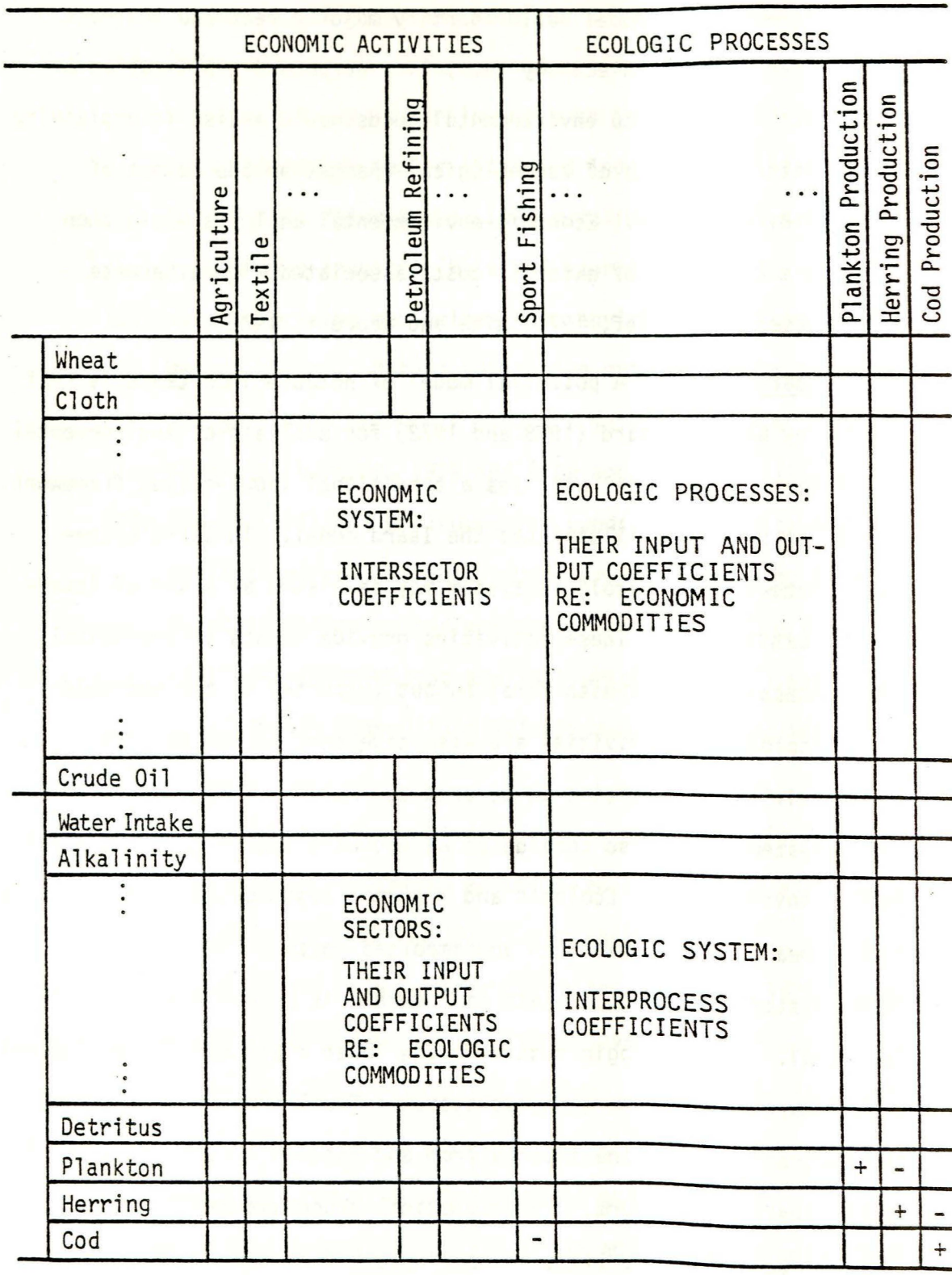

Figure 6. The Isard model of ecologic-economic linkages.

Source: Isard, 1968, p. 87.

Drawbacks of the Isard Model of economic-ecologic linkages include severe lack of data regarding economic-ecologic, ecologic-economic, and, especially, environmental subsystem flows. Furthermore, the assumption of linear production functions must be applied to environmental processes and economic-ecologic linkages where they may not necessarily hold true. Additionally, quality of environmental goods, such as water, effect changes in production processes, violating the fixed production function assumption (Hite and Laurent, 1972, and Richardson, 1972).

Linear programming. Carter (1970) utilized a linear programming system within the traditional input-output format for investigation of technical change. Carter's model differed from the conventional input-output model by allowing two alternative input structures to each industry, one representing an average technology and the other a new technological structure. By placing constraints on the capital available, the model regulated the replacement of old technologies by the new input structures. The solution described changes in the levels of various production activities throughout the economy. Changes could consist of increases in the levels of production using new technologies and increases or decreases in production output using older input structures where technical changes were embodied in capital stock subject to overall investment constraints. Incremental coefficients, representing new input structures, imply changes proportional to investment rather than time. Use of information on new technologies may also be added to the model data base as it becomes available, increasing the long-run adaptability of the model.

Dynamic analysis. Carter (1974) also applied dynamic analysis to conventional input-output techniques for investigation of changing

energy technologies and pollution abatement activities. Incremental changes in base year matrices were introduced to simulate adoption of new techniques of energy production and implementation of stricter controls on pollution emissions. The effects of structural changes were measured as impacts on economic growth of the economy.

Resources For the Future model. Another, more inclusive, model worthy of attention was put together by Resources For the Future (Ridker, 1972). This model may provide a better analysis of technical change and technological externalities over time. The core of the model is a dynamic input-output analysis to which other subsidiary models are attached. The model is used to determine changes and projections for the U.S. economy over a time horizon of 33 years, from 1967 through 2000. Given changes in demographic characteristics and economic growth, the model describes resource requirements, pollution loadings, economic activity, and changes in technology. Final consumption is determined by alternative demographic characteristics imposed on the core model. Resource use, pollution, pollution treatment, and treatment cost coefficients dependent upon production output, were used to evaluate environmental quality and costs over the time horizon. Changes in employment and the labor force are measured to determine social impacts of changes in production. The model also considers changes in input structures, and technical change, over the time horizon concerned. By continuously evaluating changes in environmental, economic and social variables over time, this model is able to describe interdependencies among and within subsystems of the model.

Summary. Ideally, resource agencies might strive for application of the Resources For the Future model (Ridker, 1972). Secondarily, an

analysis based on the Isard model of ecologic-economic linkages, such as the Hite and Laurent (1972) or Victor (1971) applications, might provide some general information on flows between the economy and the environment. However, on a more practical level, impact matrices for analysis of resource use and social costs and the linear programming approach to interindustry analysis might yield more information at a lesser cost.

Evaluation of technical change and associated impacts could be handled within a linear programming framework, as stated previously, by imposing constraints on supply of goods available and investment levels, and changing prices of goods used as inputs. Investigation of further application of the dual problem statement may also yield information on the shadow prices of natural resource inputs to production.

Construction of impact matrices for examination of direct and indirect analysis of social and environmental externalities is another potential field of endeavor for resource agencies. For example, the application of this approach to water use in western states provides a valuable data base for resource agencies wishing to evaluate impacts of alternative management plans or devise policy guidelines for further water use. Clearly, application of impact matrices to analysis of social costs and benefits associated with production technologies may also provide information to decision-makers. Direct and indirect social impacts of alternative plans may be evaluated by use of impact matrices as in the Bergman (1972) analysis of employment of women and minorities.

CHAPTER IV

CONCLUSION

Summary

Model 428, developed by Snyder, was evaluated with regard to two kinds of technological impacts, technological externalities and secondary effects. This study concentrated on the input-output analysis, which comprised the economic component of the model, because technological impacts could not be assessed unless they interfaced with that portion of the model. The study determined that the input-output analysis of the model could not satisfy the criteria derived for evaluation of externalities or secondary effects.

Criteria for technological externalities, especially external costs, are not internal to model processes. Environmental goods are considered free inputs to the economic system. Externalities, by definition, are not included in economic transactions and, therefore, not considered in sales and purchases described by the input-output analysis. Alternate models and techniques were suggested to replace or complement the input-output model component in order that technological externalities might be assessed. Impact matrices were strongly suggested for analysis of externalities considering data and monetary constraints.

While the input-output model can evaluate certain multiplier impacts, business, income, and employment changes; it cannot assess

secondary impacts as defined. Criteria external to model processes are necessary in order to evaluate secondary effects of management alternatives.

Model criteria were also devised for assessment of technological change, specifically technical change in production processes. Evaluation of technical change, either introduction of new production processes or changes in production techniques, requires two sets of input-output data over a particular time interval or a dynamic model with constant inputs over time. The input-output analysis considered did not have the data base to evaluate technical change. By definition, the input-output analysis considered is a static model and therefore cannot evaluate other technological changes.

Some general guidelines for technology assessment systems were drawn from the literature to determine whether input-output analysis would be a useful component of a technology assessment system. Input-output analyses would provide information on conventional socioeconomic impacts. If methods of assessing technological change and external effects were incorporated within the model, more information on impacts of technology could be derived for use by resource planners and decision-makers.

The model developed by Snyder contains four components: an input-output analysis, an occupational labor force analysis, an employee-to-cohort allocation technique, and a demographic model. Because the input to the input-output analysis drives the models as a whole, impacts cannot be evaluated by other components of the model unless they interface with the economic portion of the model. However, the model as a whole does evaluate conventional socioeconomic impacts such as changes

in total gross output, income and business multiplier impacts, labor force changes and population changes, and therefore would be useful in this respect. Should resource agencies attempt to institute a technology assessment program, more appropriate models for analysis of technological impacts should be investigated.

Recommendations

Suggestions for future research effort include:

(1) Application of impact matrices in conjunction with input-output analysis for measurement of social indicators relevant to resource management plans,

(2) Application of an appropriate environmental analysis, especially resource impact matrices, to an input-output model to evaluate U.S. Forest Service and other resource agencies' management plans with special attention to cost reduction methods, and

(3) Investigation of more appropriate analytical tools for evaluation of technologically induced impacts recognizing the particular model's limitations; including cost of data acquisition, time constraints of the model, assumptions on which the model is based, and problems inherent to the model's analytical framework.

SELECTED BIBLIOGRAPHY

Ayres, Robert U. and Ivars Gutmanis. "Technological Change, Pollution, and Treatment of Cost Coefficients in Input-Output Analysis." In Population, Resources, and the Environment, Ridker (ed.), pp. 313-37. U.S. Government Printing Office, 1972.

Ayres, Robert U. and Allen V. Kneese. "Production, Consumption, and Externalities." American Economic Review 59 (June 1969): 282-97.

Barkley, Paul W. and David W. Seckler. Economic Growth and Environmental Decay: The Solution Becomes the Problem. Harcourt Brace Jovanovich, Inc., 1972.

Baumol, William J. Economic Theory and Operations Analysis. Prentice Hall, Inc., 1972.

Bergmann, Barbara R. "Assessing the Impact of Alternative Economic Outcomes on Social Objectives." In Input-Output Techniques, A. Brody and A. P. Carter (eds.), pp. 31-43. North Holland Publishing Co., 1972.

Brody, A. and Ann P. Carter (eds.). Input-Output Techniques. Proceedings of the Fifth International Conference on Input-Output Techniques, Geneva, January 1971. North Holland Publishing Co., 1972.

Brooks, Harvey and Raymond Bowers. "Technology: Processes of Assessment and Choice." In Technology and Man's Future, Albert H. Teich (ed.), pp. 219-33. Saint Martin's Press, 1972.

Buchanan, J. M. and W. C. Stubblevine. "Externalities." Economica, N.S. 29 (1962) 116:371-383.

Carter, Ann P. "A Linear Programming System Analyzing Embodied Technological Change." In Contributions to Input-Output Analysis, Carter and Brody (eds.), pp. 77-98. North Holland Publishing Co., 1970.

_____. Strucutral Change in the American Economy. Harvard University Press, 1970.

_____. "Energy, Environment and Economic Growth." Bell Journal of Economics and Management Science 5 (Aut. 1974): 578-92.

Carter, A. P. and A. Brody (eds.). Contributions to Input-Output Analysis. 2 vols. Proceedings of the Fourth International Conference on Input-Output Techniques, Geneva, January 1968. North Holland Publishing Co., 1970.

Carter, H. O. and D. Ireri. "Linkage of California-Arizona Input-Output Models to Analyze Water Transfer Patterns." In Contributions to Input-Output Analysis, Carter and Brody (eds.), pp. 139-67. North Holland Publishing Co., 1970.

Cetron, Marvin J. "The Trimatrix--An Integration Technique for Technology Assessment." In The Methodology of Technology Assessment, Cetron and Bartocha (eds.), pp. 137-71. Gordon and Breach, Science Publishers, Inc., 1972.

Cetron, Marvin J. and Bodo Bartocha (eds.). The Methodology of Technology Assessment. Gordon and Breach, Science Publishers, Inc., 1972.

Coates, Joseph F. "Technology Assessment--How Will It Work." Standardization News 2, 11 (1974a): 30-32, 59.

_____. "Technology Assessment." In McGraw-Hill Yearbook of Science and Technology. McGraw-Hill Book Co., 1974b.

Daddario, Emilio Q. "Technology Assessment." In Technology and Man's Future, Albert H. Teich (ed.), pp. 201-19. Saint Martin's Press, 1972.

Daly, Herman E. "On Economics as a Life Science." Journal of Political Economy 76 (1968): 392-405.

Davis, H. C. A Multi-regional Input-Output Model of the Western States. Ph.D. Dissertation. University of California, Berkeley.

Detwyler, Thomas R. (ed.). Man's Impact on Environment. McGraw-Hill Book Company, 1971.

Economic Research Service, Natural Resources Research Service, Southwest Resource Group. "Forest Resource Management Analysis, Phase I Report." By Ronald Drake, Stanley Randall, and John Wilkins. July 31, 1971.

Elton, Charles S. "The Invaders." In Man's Impact on Environment, Detwyler (ed.), pp. 447-58. McGraw-Hill Book Company, 1971.

Freeman, David M. Technology and Society: Issues in Assessment, Conflict and Choice. Rand McNally College Publishing Co., 1974.

Gordon, T. J. and H. S. Becker. "The Use of Cross-Impact Matrix Approaches in Technology Assessment." In The Methodology of Technology Assessment, Cetron and Bartocha (eds.). Gordon and Breach, Science Publishers, Inc., 1972.

Gray, S. L. and J. R. McKean. An Input-Output Analysis of Water Use in Boulder, Larimer and Weld Counties, Colorado. General Series 953, Colorado State University Experiment Station, Fort Collins, April 1976.

Herfindahl, Orris C. and Allen V. Kneese. Economic Theory of Natural Resources. Resources For the Future, Inc. Charles E. Merrill Publishing Co., 1974.

Herzog, H. W., Jr. and Ronald G. Ridker. "The Model." In Population Resources and the Environment, Ridker (ed.), pp. 301-311. U.S. Government Printing Office, 1972.

Hirsch, Werner Z., Sidney Sonenblum, and Jerry St. Dennis. "Estimating the Quality of Urban Life with Input-Output Analysis." In Input-Output Techniques, Brody and Carter (eds.), pp. 44-60. North Holland Publishing Co., 1972.

Hite, James C. and Eugene A. Laurent. Environmental Planning: An Economic Analysis--Applications for the Coastal Zone. Praeger Special Studies in U.S. Economic and Social Development. Praeger Publishers, 1972.

Holtermann, S. E. "Externalities and Public Goods." Economica N.S. 39 (February 1972): 78-87.

Huddle, Franklin P. "The Social Function of Technology Assessment." In Technology Assessment: Understanding the Social Consequences of Technological Applications, Raphael G. Kasper (ed.), pp. 149-73. Praeger Publishers, 1972.

International Research and Technology Corporation. Part I: "Technological Change as an Explicit Factor of Economic Growth." Effects of Technological Change On, And Environmental Implications of an Input-Ouput Analysis for the United States Economy, 1967-2020. Resources For the Future, 1971.

Ireri, D. "California-Arizona Economic Interdependencies and Their Water Use Patterns." Unpublished Ph.D. Dissertation, University of California, Davis, 1967.

Isard, Walter. Methods of Regional Analysis: An Introduction to Regional Science. The MIT Press, 1960.

_____. "Some Notes on the Linkage of the Ecological and Economic System." Regional Science Association Papers 22 (1968): 85-96.

Isard, Walter, Charles L. Choguill, John Kissin, Richard H. Seyfarth and Richard Tatlock. Ecologic-Economic Analysis for Regional Development. Collier-MacMillan Limited, The Free Press, 1972.

Kasper, Raphael G. (ed.). Technology Assessment: Understanding the Social Consequences of Technological Applications. Praeger Publishers, 1972.

Krutilla, John V. and Anthony C. Fisher. The Economics of Natural Environments. Resources For the Future, Johns Hopkins University Press, 1975.

Leontief, Wassily. "Quantitative Input-Output Relations in the Economic System of the United States." The Review of Economics and Statistics 18 (August 1936).

_____. "Environmental Repercussions and the Economic Structure: An Input-Output Approach." Review of Economics and Statistics 52 (1970): 262-71.

Leontief, Wassily and Daniel Ford. "Air Pollution and the Economic Structure: Empirical Results of Input-Output Computations." In Input-Output Techniques, Brody and Carter (eds.), pp. 9-30. North Holland Publishing Co., 1972.

Lofting, E. M. and P. H. McGauhy. "Economic Evaluation of Water: Part IV, An Input-Output and Linear Programming Analysis of California Water Requirements." No. 116. Water Resources Center, UCLA, Berkeley, 1968.

Mansfield, Edwin. Technological Change. W. W. Norton & Co., Inc., 1971.

Marshall, Scott. Personal Communication. May 1976.

Mayo, Louis H. "The Management of Technology Assessment." In Technology Assessment: Understanding the Social Consequences of Technological Applications, Kasper (ed.), pp. 71-122. Praeger Publishers, 1972.

Miernyk, William H. The Elements of Input-Output Analysis. Random House, 1965.

National Bureau of Economic Research, Conference on Research in Income and Wealth, Vol. 18. Input-Output Analysis: An Appraisal. Princeton University Press, 1955, 1957.

Nicholson, Walter. Microeconomic Theory: Basic Principles and Extension. The Dryden Press, Inc., 1972.

Nourse, Alan E. "Hormones and Cancer: Is There a Connection." Woman's Day Magazine (February 1976): 34, 36, 38, 108.

Overly, Don H. "Introducing Societal Indicators into Technology Assessment." In The Methodology of Technology Assessment, Cetron and Bartocha (eds.), pp. 63-91. Gordon and Breach, Science Publishers, Inc., 1972.

Prest, A. "Cost-Benefit Analysis: A Survey." The Economic Journal (December 1965): 683-735.

Ralph, Christine A. "A Macro-Assessment Methodology." In The Methodology of Technology Assessment, Cetron and Bartocha (eds.), pp. 173-94. Gordon and Breach, Science Publishers, Inc., 1972.

Richardson, Harry W. Input-Output and Regional Economics. Weidenfeld and Nicolson, 1972.

Ridker, Ronald G. (ed.). Population, Resources, and the Environment. Vol. III of Research Reports, Commission on Population Growth and the Future of America. U.S. Government Printing Office, 1972.

_____. "The Economy Resource Requirements and Pollution Levels." In Population, Resources, and the Environment, Ridker (ed.), pp. 35-57. U.S. Government Printing Office, 1972.

Snyder, John M. "Relationships between Resource Management and Regional Population Dynamics." Master's Thesis, Colorado State University, 1974.

_____. "A Systems Approach to Socio-Economic Impact Analysis." Agreement No. 16-428-CA, U.S. Forest Service, Region 2. Unpublished Report.

U.S. Department of Agriculture, Economic Research Service. USDA Procedures for Planning Water and Related Land Resources. March 1974.

_____. Working Paper, The Economic Base of the Platte Basin--Wyoming. By John Tillman and David Langemeier. January 1976.

_____. Natural Resources Economic Division. "Tentative Guidelines for Implementing the Proposed Principles and Standards for Planning Water and Related Land Resources, Methodology: Procedural Guidelines, USDA Handbook." Draft, June 1973.

U.S. Department of Commerce, Bureau of Economic Analysis, Social Economics and Statistics Administration, Interindustry Economics Division. "The Input-Output Structure of the U.S. Economy: 1967." The Survey of Current Business 54, 2 (February 1974): 24-56.

Vaccara, Beatrice. "Changes Over Time in Input-Output Coefficients for the United States." In Contributions to Input-Output Analysis, Carter and Brody (eds.), pp. 238-260. North Holland Publishing Co., 1970.

Victor, P. A. "Input-Output Analysis and the Study of Economic and Environmental Interaction." Ph.D. Dissertation, University of British Columbia, April 1971.

Webster's Seventh New Collegiate Dictionary. G. and C. Merriam Co., 1970.